Top-Down Constraints on Fossil Fuel CO_2 Emissions for Three Urban Areas of California

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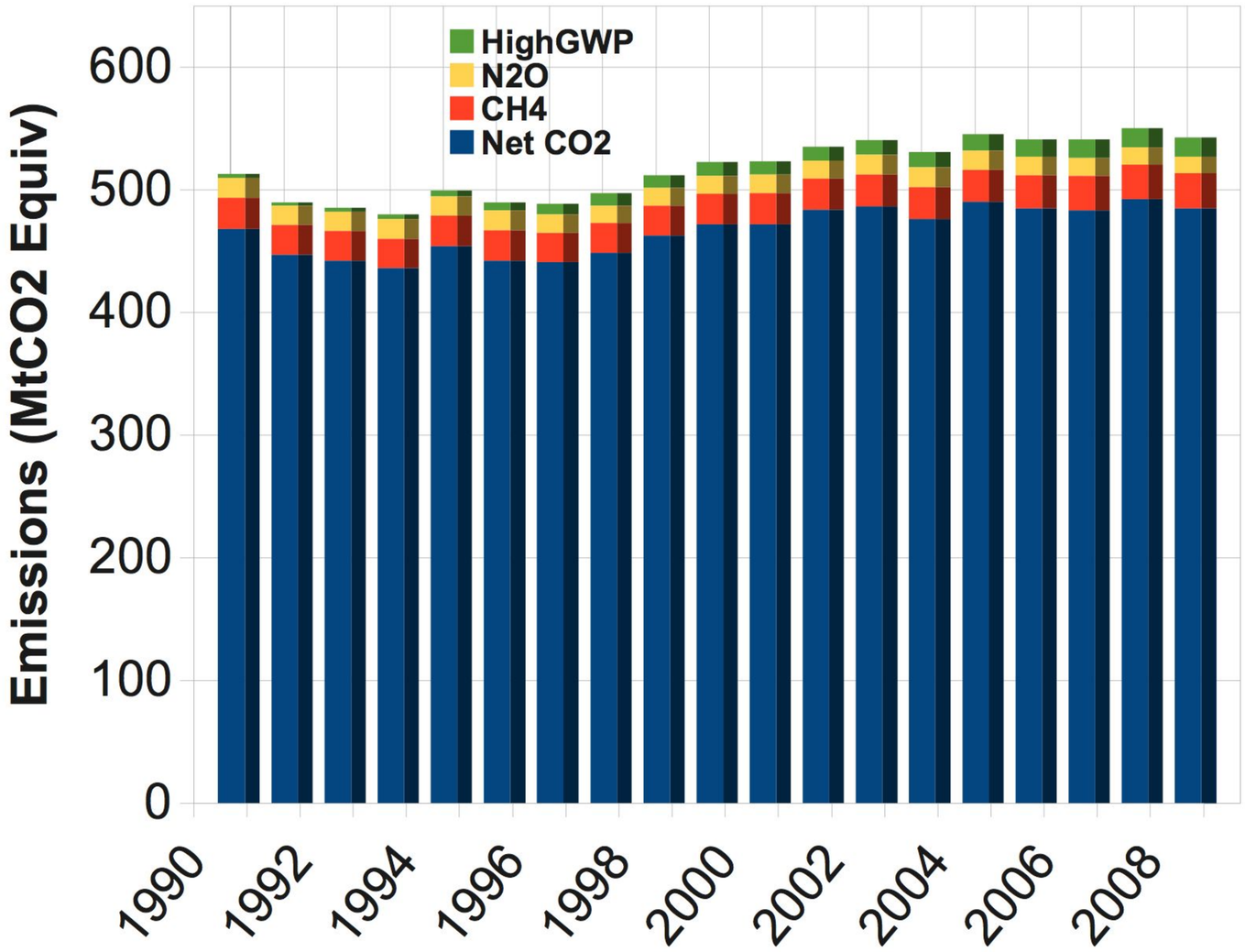
Outline

- **Motivation**
  - — Need for of fossil fuel CO_2 (C_{ff}) emission inventory validation at regional scale
- **Atmospheric top-down approach**
  - — Atmospheric signals diagnostic of emissions
- **Results**
  - — Initial comparisons of measured and predicted C_{ff} for Central California and LA Basin
- **Conclusion**
  - — Fossil fuel CO_2 emissions consistent with current CARB inventory estimate to ~ 10%

California GHG Emissions

- **California is the first state in US to legislate GHG emission controls**
  - **2006 Global Warming Solutions Act (AB-32): 1990 levels by 2020**
  - **Executive Order S-3-05: Reduce emissions to 80% below 1990 by 2050**
- **Inventory suggests recent emissions relatively constant**
- **Atmospheric inverse method provides independent check**

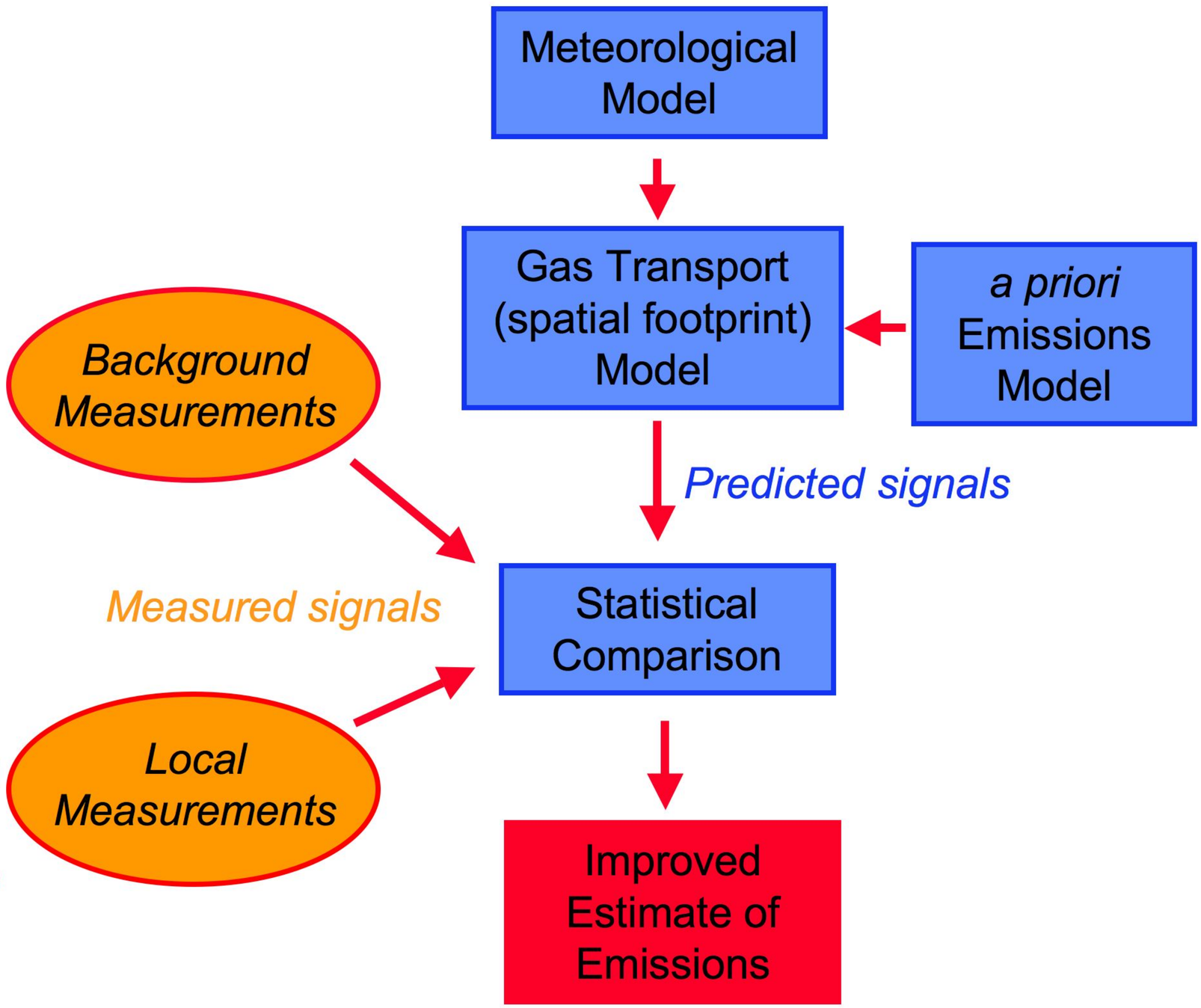
California GHG Emissions over Time



[*CARB*, 2010]

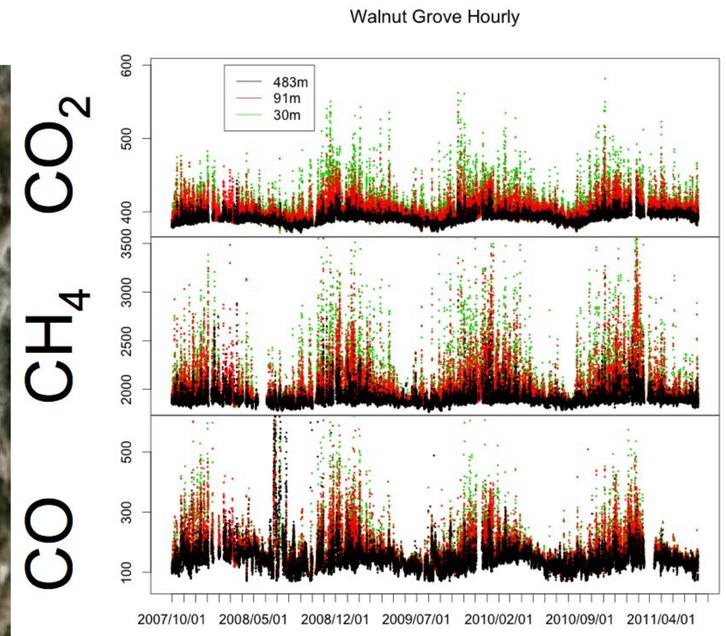
Top Down Approach

- **Measurements:**
  - — Background Mead.
  - — Local measurements
- **Combined with Models:**
  - — a Priori Emissions
  - — Meteorology
  - — Gas transport
- **Statistical comparison yields:**
  - — Improved estimate of emissions



Measurements in Central and Southern California

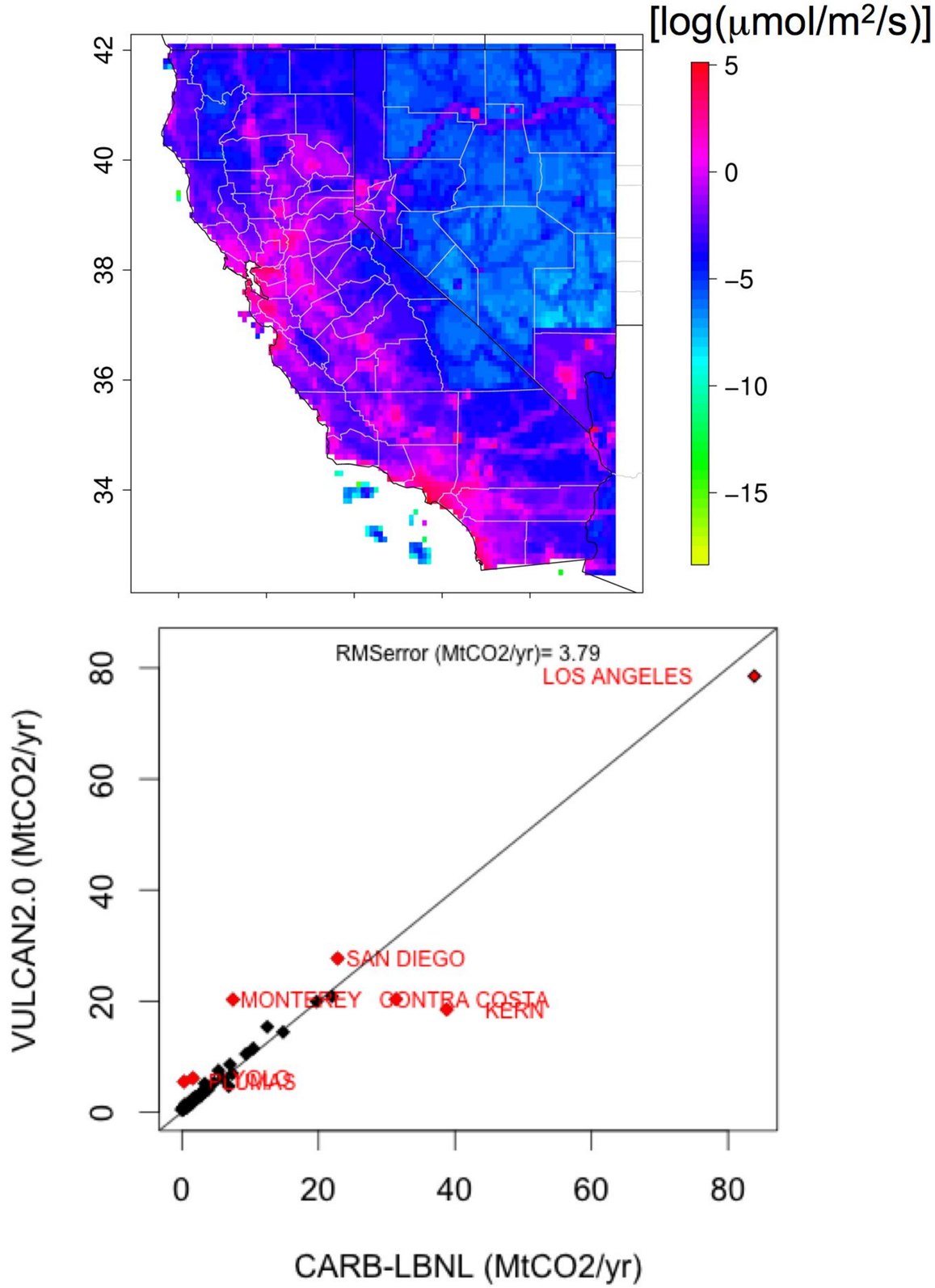
Walnut Grove Tower 2009-2010
Continuous CO_2,CO: 91, 483 m
Flask CO2, $^{14}CO_2$, CO: 91 m
(calgem.lbl.gov)



Pasadena, CA, June 2010
Continuous CO_2,CO: 15 m
Biweekly midday average flasks CO2, $^{14}CO_2$

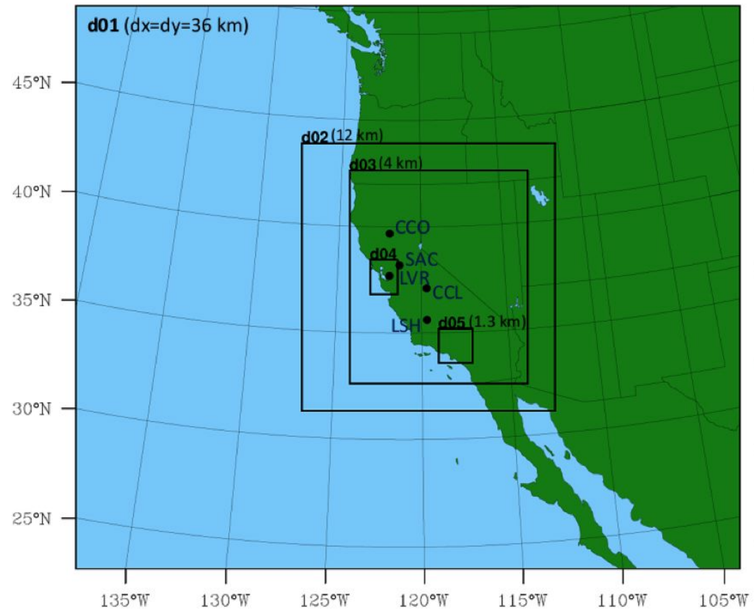
a priori Fossil Fuel Emission Map

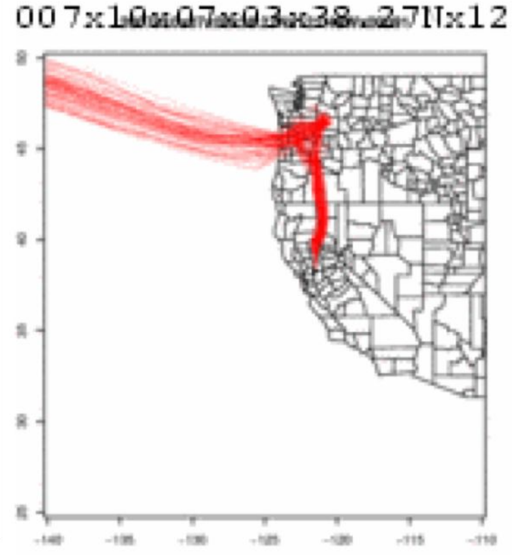
- **VULCAN2.0 Fossil Fuel CO2 Emission Inventory (Gurney et al., 2009)**
  - **— Diurnal emissions by day of week, and month at 0.1 degrees**
  - **— Multiple data sources for US**
  - **— Careful attention to quality control**
- **Comparing 2002 VULCAN2.0 with LBNL/CARB county level energy analysis (CARB, 2008)**
  - **— Total in-state ffCO2 emissions (~ 370 $MtCO_2$) match to within 5%**
  - **— RMS differences ~ 4 $MtCO_2$ (~ 30%)**



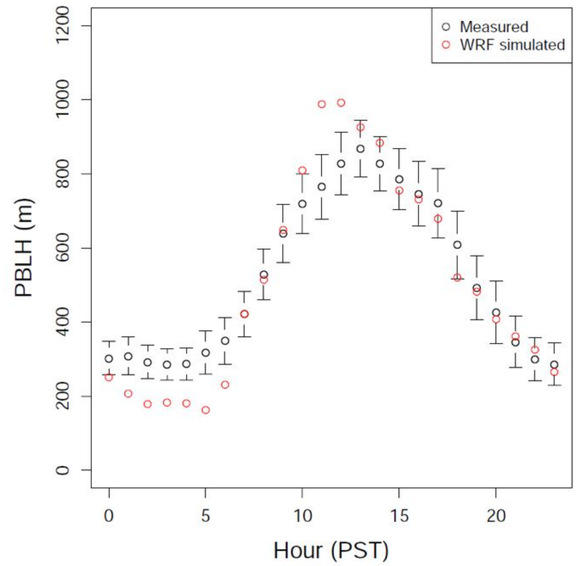
Meteorology and Transport

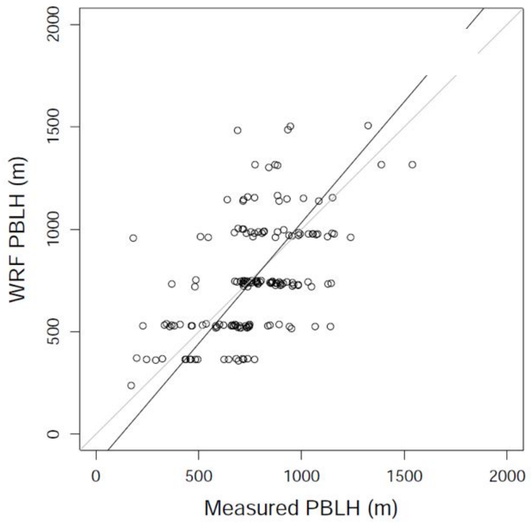
- **WRF-STILT for California**
  - **5 Domains over W. US**
  - **4 km for California**
  - **1.3 km for SF Bay & LA Basin**
  - **Ensemble receptor trajectories**





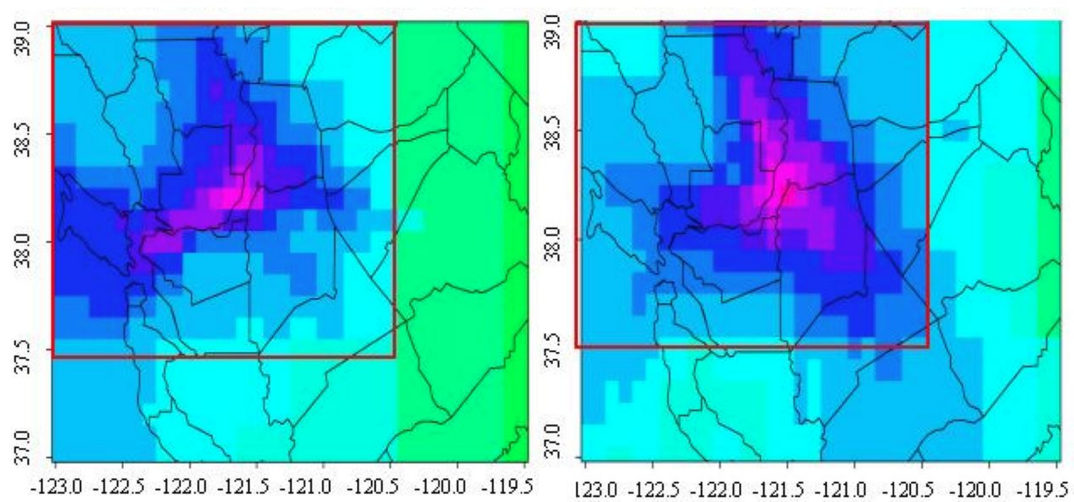
May-June, 2010 Cal Tech WRF and Lidar





- **Errors evaluated using profiler/lidar obs**
  - **Bias appears negligible during day**
  - **Propagated RMS errors 20-50% uncertainty in afternoon CH_4 signals (Jeong et al., 2011)**
- **Footprints capture sensitivity to emissions**

Fall WGC Footprints Winter



Estimating Fossil Fuel CO_2

- Measure $\Delta^{14}C$, C_{obs} from tower flask obs and background air
- Flask measurements determine

  $C_{ff} = C_{obs}\,(\Delta obs - \Delta bck)/\,(\Delta ff - \Delta bck)$

  $- C_{eco}\,(\Delta eco - \Delta bck)/\,(\Delta ff - \Delta bck)$

  C_{ff} to ~ 1 ppm if σ_{Δ} ~ 2.8 ‰

- Flask measurements determine CO: C_{ff}

  $R = (CO_{obs} - CO_{bg})/\,C_{ff}$

  - 2009-2010 WGC

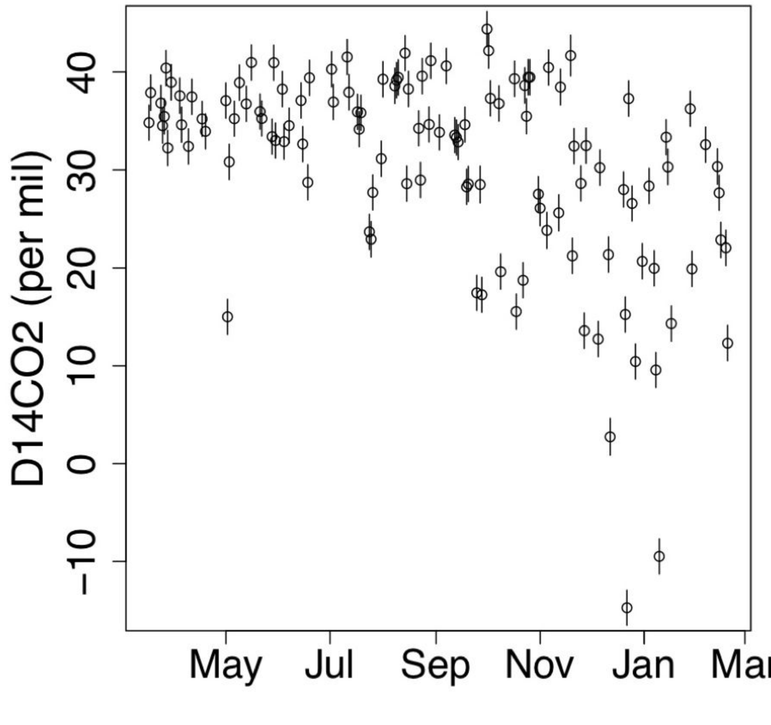
  $R = 12$ +/- 1 ppb CO /ppm $ffCO_2$
- Estimate continuous $C_{ff}(t)$ as

  $C_{ff}(t) = (CO_{obs}(t) - CO_{bg}(t))\,/\,R$
- Uncertainties:

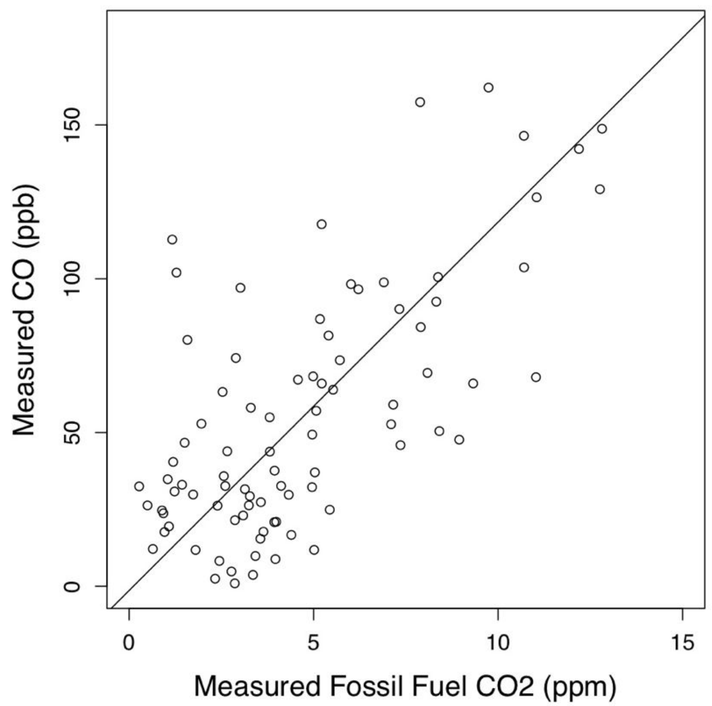
  - errors in estimated CO_{obs}, CO_{bg}

  - variation of R

$\Delta^{14}CO_2$ vs time at WGC

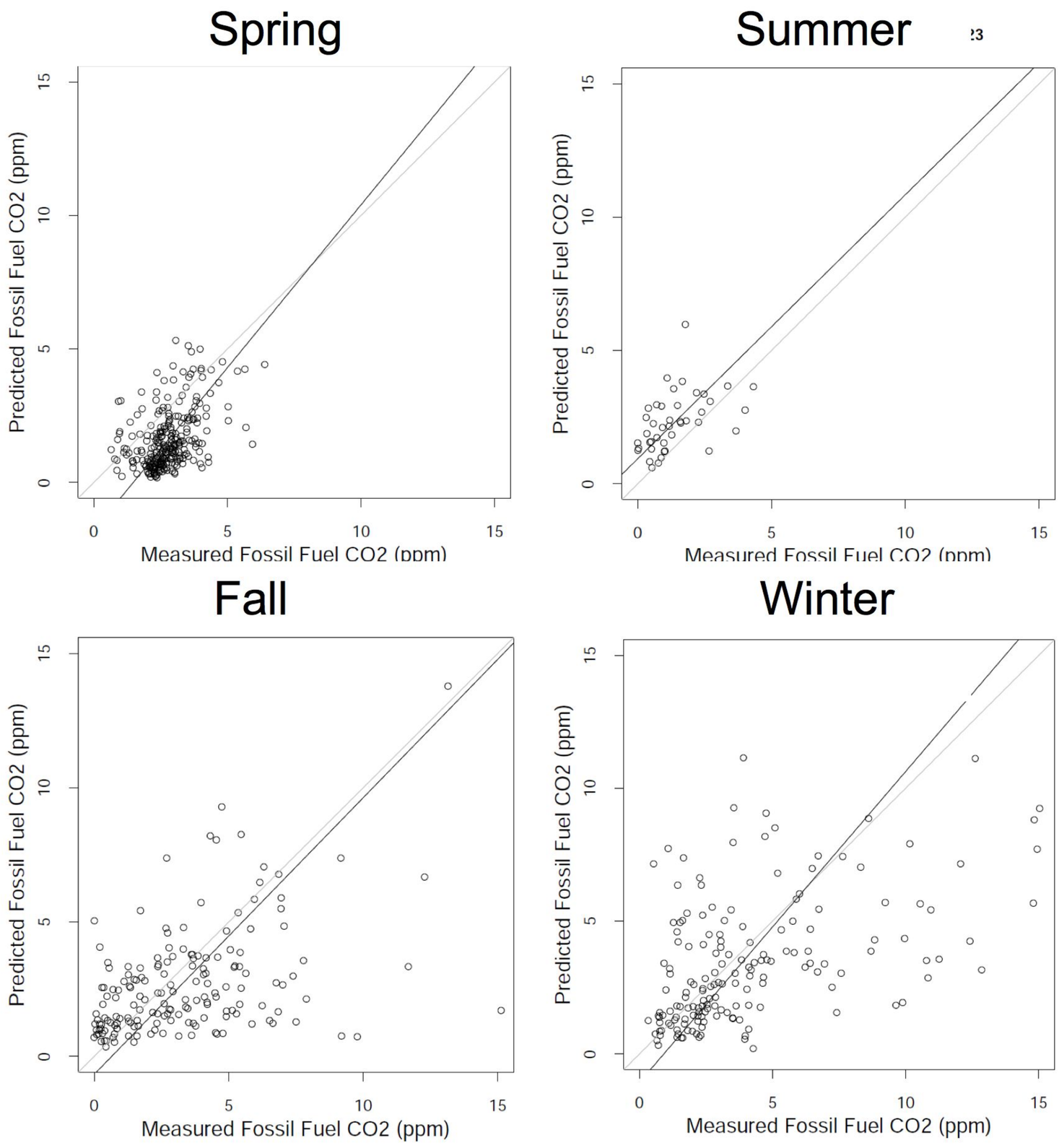


CO vs Cff at WGC



Measured and Predicted ffCO2 Walnut Grove by March, 2009 - Feb, 2010

- **Data from 12-23 hr local interval**
  - — require well-mixed (91 - 483 m differences small)
  - — CO fire anomalies removed in summer
- **Predicted vs measured slopes ~ consistent with unity +/- ~ 10 %**
  - — spring had higher flask CO:CO_{2ff}
  - — similar (noisier) results obtained w/ 12-17 hr subset



Measured and Predicted $ffCO_2$ May-June, 2010 CalTech

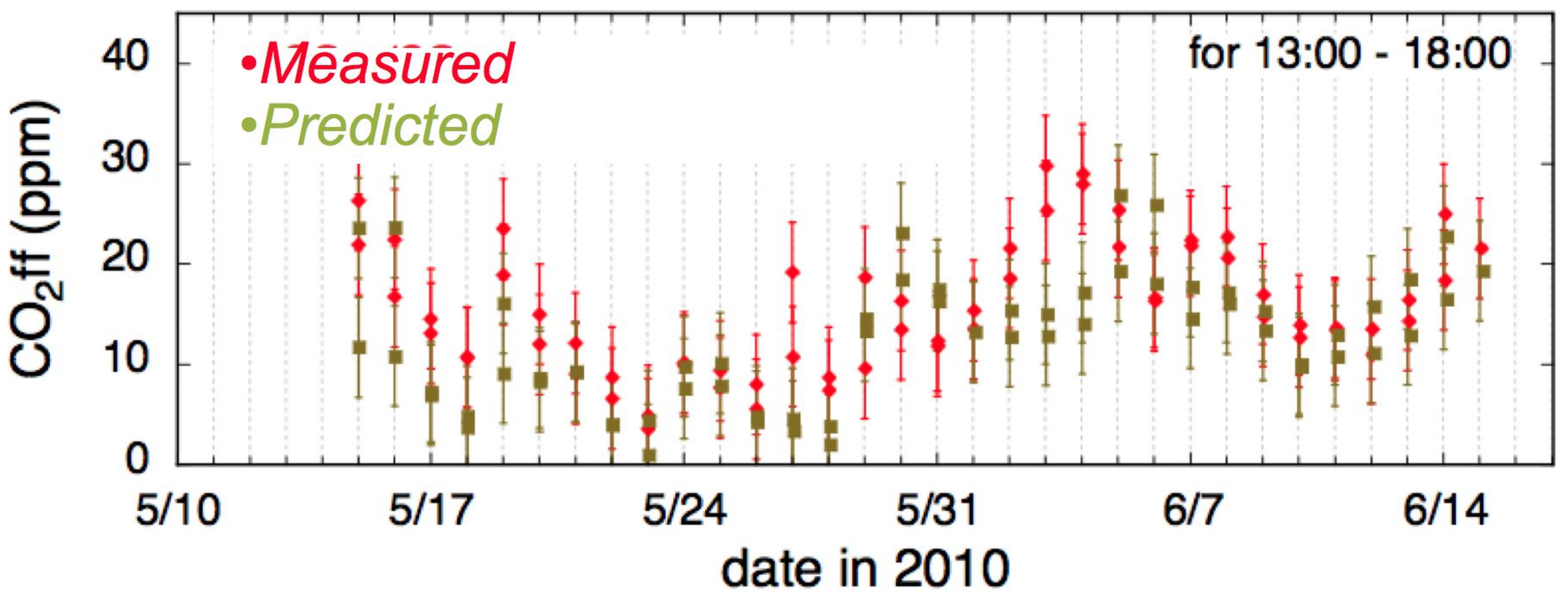
— Adopt constant $CO:CO_{2ff}$ ratio

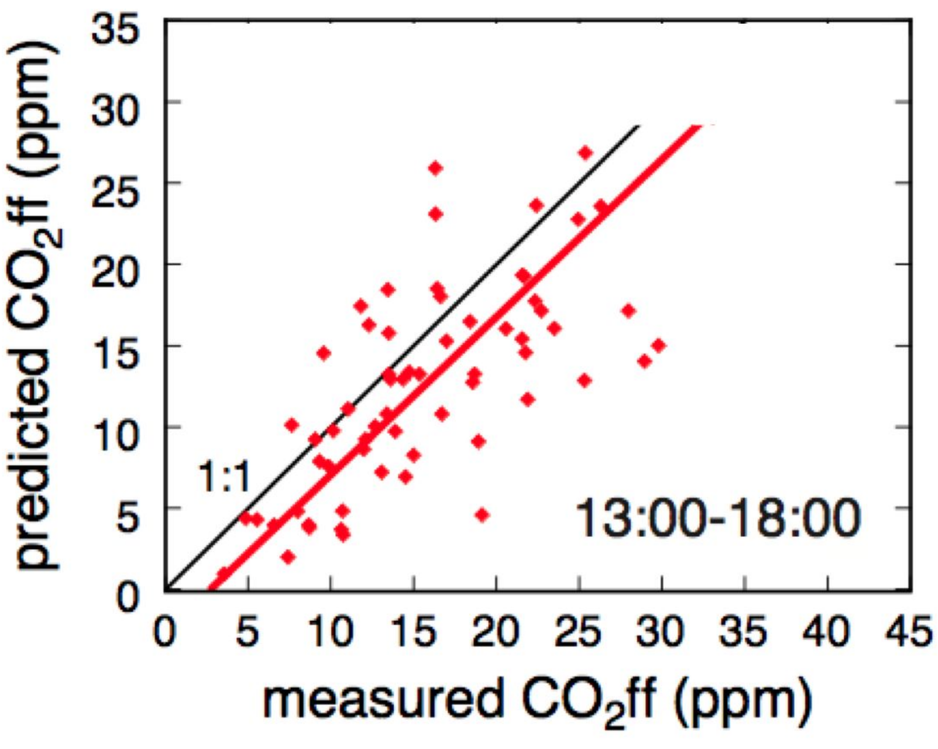
- R = 11 ppb CO/ ppm CO_{2ff} (Wunch et al., 2010)
- Consistent with two bi-weekly average flasks

— Predicted midday mixing ratios capture measured synoptic variations

— Slope of predicted on measured signals match to +/- 10%

- Suggests LA emissions ~ consistent with VULCAN map





Conclusions

- **Fossil fuel CO_2 dominates CA state total GHG emissions**
- **VULCAN2.0 map matches CA total CO_{2ff} inventory**
  - **Potentially significant differences apparent at county level**
- **Atmospheric radiocarbon measurements valuable**
  - **One year record at Walnut Grove resolves synoptic but not diurnal variations**
  - **Carbon monoxide used as a continuous tracer for combustion -- biomass burning can be significant error term**
- **Atmospheric modeling suggests VULCAN emission map captures CO_{2ff} emissions to ~ 10 % for SF Bay, Sacramento, and LA Basin**
  - **Longer time periods and additional measurement sites will improve estimates**

Thank You